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THE BLACK SMUT, OR BUNT, OF RICE (ORYZA SATIVA LINNÆUS) IN THE PHILIPPINES [1]

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SEVEN PLATES

INTRODUCTION AND HISTORICAL REVIEW

The first authentic report on the occurrence of black smut, or bunt, of rice caused by *Tilletia horrida* was by Takahashi in Japan, in 1896.(21) It is believed to be indigenous to that country and was inadvertently introduced into South Carolina, United States, through the importation of seed rice from Japan by the Clyde Steamship Company of Georgetown in 1896.(2) In June, 1899, Anderson(1) reported a new *Tilletia* parasitic on *Oryza sativa* Linn., discovered in South Carolina in 1898, which was named with F. S. Earle's assistance *Tilletia corona* Scribn. [now *Tilletia rotundata* (Arth.) Ell. and Ev.].(2, 18) This identification caused some confusion, and Earle(9) and, later, Ander-

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son(2) called attention to this mistake and amended the previous report by stating that the rice smut in South Carolina was not due to *Tilletia corona* but to *T. horrida* Tak. In 1903, under the binomial *Tilletia horrida,* rice bunt was reported from Louisiana where it is believed to have occurred also on wild grasses.(23) This was probably a result of the confusion brought about by the first paper of Anderson(1) that also confused Filter(10) and others who state that *Tilletia horrida* Tak. and *T. corona* Scribn. are identical, and that *T. rotundata* (Arth.) Ell. and Ev. occurs on rice.(2) A treatise on rice diseases in Louisiana by Fulton(11) makes no mention of its occurrence on wild grasses; therefore, the report of Winkler(23) here cited cannot be confirmed. Moreover, Butler(5) states that it is not found on other hosts.

How early the disease was transported into the Philippines is not definitely known. The writer,[3] however, while making a survey of general plant diseases in various parts of the Islands, observed it first at the Alabang Rice Experiment Station in November, 1920, on standing rice of a Formosan variety called "Ryuchu" which, according to information obtained from the former Bureau of Agriculture, had recently been imported, presumably for seed purposes. This being the case, the parasite may be considered introduced. The affected panicles exhibited typical, conspicuous, external and internal black-smut features. No report of its appearance in the Philippines was made at the time as the writer then left the Government service. Later, along about the third quarter of 1930, after a lapse of almost a decade, the same disease was observed again in the same locality, now on native varieties, affecting by actual count 4 to 6 per cent in a panicle. More grains showed the presence of spores of the causal fungus adhering to them which had escaped through the fissures of the glumes or by contact with affected grains. The occurrence of a large number of diseased plants in 1930 provided sufficient material for observation and afforded an opportunity for more detailed study. While the disease at present may not be considered of great importance, under favorable circumstances it may become much more virulent. Just how serious it will be in its comparatively new territory remains to be seen. It may be safely stated, however, that it is likely to increase in severity through the promiscuous planting of seeds taken from diseased heads. We should also realize that any disease, to however slight a degree it may prevail in its territory, becomes more or

[3] Employed by the former Bureau of Agriculture.

less established on the spot, lying in wait for opportunities to give trouble to the succeeding crop. It is not safe to assume that a parasite which is of little or no economic importance in one country may not prove a destructive parasite when transported into another country.

In 1926, Bureau of Agriculture Circular No. 183, entitled Rice Diseases and Their Control, by N. G. Teodoro and J. R. Bogayong, was published.[4] This, however, was largely a compilation, which adduced no evidence that this disease at least had been seen or had actually appeared in the Philippines. The senior author himself said that he had not seen specimens of the black smut of rice before when photographs were furnished him by the writer. When fresh specimens and photographs of rice bunt were given to Dr. G. O. Ocfemia, professor of plant pathology, College of Agriculture, Los Baños, P. I., he also informed the writer that he had not actually seen the bunt of rice before. In fact, apparently no record has heretofore appeared in Philippine literature, indexes of fungi, or in herbaria, of the disease having been reliably seen or collected by others in or previously reported from the Philippines. Specimens of this parasitic fungus have now, however, been entered in the mycological collection of the Bureau of Science for the convenience of those who may wish to refer to it in the future.

DISTRIBUTION AND IMPORTANCE

As the rice bunt easily escapes detection in the field, its actual distribution may not be possible to determine definitely. Outside of Rizal Province, the distribution of black smut in the Philippines is not known, as no systematic reconnoissance has been undertaken. In the United States, it was found in South Carolina in 1899,(1) in Louisiana in 1903,(23) in Arkansas in 1926,(14) but it is not believed to have ever appeared in California.(15) This disease is widespread in eastern and southern Asia, including Malaya, and is known definitely in Japan, India, Java, Siam, and China.(4, 5) There is also a report that rice bran imported into Germany from Siam and Burma was constantly being found contaminated with rice bunt spores,(4, 5, 10) which must have been present in appreciable quantities to render them noticeable. Spores of the fungus were also detected in rice flour in South Carolina.(1) Butler(4) was inclined to think that

[4] Issued in pamphlet form and published also in Philip. Agr. Rev. 19 (1926) 237–241.

the "species is more widely distributed in South-Eastern Asia than appears from the scanty records." Rhind(17) in 1925 reported that the disease was more prevalent in India than usual. Duport(8) and Vincens(22) reported having observed it in French Indo-China. This rice disease occurs also in British Guiana, according to Stevenson.(20)

In Japan, Takahashi(21) reported that this disease affects only a few grains in the panicle, and according to Miyake(16) it is not prevalent. In the United States, however, where it was casually introduced, it assumed destructive proportions, causing as much as 25 per cent damage to smutty crops in South Carolina.(11) Cook(6) considers it as probably the most serious of the diseases of rice of lesser importance. Its apperance in some countries is more or less sporadic, and the damage occasioned by this ubiquitous rice parasite in eastern and southern Asiatic rice-growing countries is generally slight; but certainly it is more destructive than the rice false smut or green smut, or other diseases known, which likewise operate on the grain. Grains attacked are good neither for seed nor for human consumption. It may lower the market value as smutty rice does not command as good a price as clean rice; and the color of the flour when smut is present to an appreciable extent may be spoiled and similar damage caused. In other words the disease reduces not only the quantity but also the quality, and though a small proportion of black smut is admissible and does not seriously reduce the yield or the quality of grain, yet even a small percentage of the smut is objectionable.

Reduction in yield is also due in part to the morphological reactions of the plants to the disease, such as stunting, failure to head, and distortion and partial sterility of the infected heads.

SYMPTOMS AND EFFECTS

Not until the grains begin to ripen does the blackening due to smut become discernible at close range; and it would seem much more difficult to detect if it happened to attack varieties having fixed pigment on the hull during maturity. Diseased panicles are carried by the culms in the same manner as the uninfected ones, and usually not all culms in the same stool bear diseased heads. The disease is recognized generally by the presence on the surface of the grains of a black, powdery or sooty mass of spores (Plate I) sticking together and usually clustered towards the tips of the unaffected hull or on their hairy portions (Plates II and III). Under ordinary conditions the heads are only

partially smutted. Some grains are covered almost entirely by the black mass of spores. Others show very little signs of the disease, while a great number are hardly distinguishable from normal grains, and thus it is that even expert observers can be deceived sometimes. This disease is more clearly differentiated if seen through a magnifier, but macroscopically it may be confused with *Helminthosporium* or other grain-inhabiting organisms of rice by anyone who is not well acquainted with these diseases.

Ordinarily the affected panicles show only a few blackened grains in one or two spikelets, but in fairly severe cases of infection more spikelets show blackened grains, but bear no fixed position in the head. Sometimes the infected grains gape or show a little separation of the tips (Plate III, *d*) as a result of the slight enlargement of some of the kernels, and occasionally also a short, somewhat beak-shaped or inverted, spurlike outgrowth (Plates II and III), capable of resisting weathering, comes out by rupturing any portion of the keel of the larger glume or lemma in severe infection, thus increasing the visibility of the fungus. This protruding spurlike structure is nothing but the shrunken or atrophied remnant of the eaten-out endosperm, which remains intact, extruded through the inclosing membrane and the inner glume by force through the multiplication of the spores inside. A careful examination with a hand lens will reveal that the remaining endosperm is practically covered with spores, and the shallow superficial cavities formed by the fungus are clearly noticeable. This is rather an extraordinary but striking indication of this grain-infesting smut and is believed to have been observed for the first time. These structures stretch out generally at an angle downward (Plate II), but occasionally upward or horizontally and are usually covered with spores, thus facilitating the latter's distribution. They are usually grayish black, but rarely pink, or purplish pink, and resemble somewhat the peculiar appearance of ergot. These characteristic features taken together are the outward symptoms of the disease.

Internally, on cautiously opening the bunted grains, one will see that the kernel is covered with a more or less transparent or gray membrane (cuticle), with the fungus transforming the ovary partly or wholly into a dense, stooty-black mass of spores (Plate III, figs. *b, c, e, f*). When this occurs in a wholesale manner, the host plant is unable to reproduce itself. This is the most distinguishing feature of the rice bunt. In the ad-

vanced stage the kernel is replaced entirely by spores (Plate III, *f*) and this is what causes the actual loss. But the heads destroyed by the fungus cannot be regarded as an absolute index of the total damage, because beyond the evident indications the presence of the fungus in the system causing a disturbance in the normal functions of the plant affects the growth and decreases the yield, as demonstrated by pot and field experiments.

ETIOLOGY

DESCRIPTION AND IDENTIFICATION OF THE FUNGUS

According to a system of classification, the parasite causing the black smut, or bunt, of rice belongs to a subgroup of the Basidiomycetes, subclass Hemibasidii. It is a species of the order Utilaginales and is included in the most important genus of the family Tilletiaceæ. It falls in the group of fungi the members of which often cause serious damage to cereals, and are considered as being among the most destructive of plant diseases. The causative fungus, *Tilletia horrida* Tak., is closely allied to the organism causing the well-known stinking smut, or bunt, of wheat, a disease of world-wide evil fame.

The gross symptoms, as determined by field observations, and microscopic examinations of the spores from infected heads indicate beyond reasonable doubt that they are typical of *T. horrida* with respect to color, shape, size, and surface features. The spores are single-celled and relatively large as compared with those of other fungi, forming a black, homogenous, pulverulent mass at maturity. The sori are found in the ovary and are enveloped in the unaffected glumes.

Spores of different stages are present, usually inside the ovary, and are variously compressed, assuming different sizes and shapes (Plate IV). The immature spores are hyaline, subhyaline, or yellowish, the latter two exhibiting blunt spines. The hyaline spores are generally smooth. Some of the young spores are shrunken and generally elongated (Plate IV, fig. 1) ; others are without contents or spinous wall-projections but with peripheral thickening (Plate IV, fig. 3). Sometimes a short narrow hypha (pseudo-pedicel) may be seen attached to the thickened portion of the young spore (Plate IV, fig. 2, which later disappear through gelatinization. Tiny bits of septate vegetative mycelium (Plate IV, fig. 6, *b, c*) have also been noticed with the spores. Subhyaline spores show clearly the arrangement of rudimentary, blunt wall-projections and their reticulose formation (Plate IV, fig. 4).

The mature spores (Plate IV, fig. 6, *a*) are opaque, olive-brown to black, globose to subglobose or occasionally elliptical; and the surface is provided with slightly colored or hyaline, spinous, scalelike projections. These echinulations, which are more conspicuous in less opaque spores (Plate IV, fig. 5), are frequently curved and pointed at the apex (Plate IV, figs. 5 and 6, *a* and Plate V, fig. 2). On mature spores they are irregularly polygonal at the base (Plate V, fig. 1) and form a band at the periphery about 2.57 to 4.28 microns in breadth.

Measurement of spores.—For purposes of comparison, spores of *Tilletia horrida* found on rice in the Philippines were obtained from infected grain in which the kernel is more or less replaced by the black powdery mass of spores, and mounted in water. On account of the slight variability in size of spores, and the disagreement in the measurements made by other workers, a sufficiently large number of measurements or a total of 200 globose spores and 200 elongated spores were measured both for length and width, to determine accurately the average size.

Compared with measurements given by other authors after deducting the breadth of the band of scales included in the writer's measurements, it will be seen that the spores of rice bunt found in the Philippines approximate closely the measurements made by workers in other countries, especially those of Takahashi, who first described the species.

TABLE 1.—*Spore measurements given by other authors.*

Takahashi.(21)
Spores globose, irregularly rounded, or broadly elliptical; rounded, 18.5 to 23.0 μ; elongated, 22.5 to 26.0 by 18.0 to 22.0 μ.

Anderson.(1)
Spores spherical to broadly elliptical, 26 to 30 μ diameter, including the hyaline envelope, 2 to 3 μ thick.

Fulton.(11)
Spores spherical to slightly oval, 22 to 28 μ.

Stevens.(19)
Spores subspherical to spherical, 22 to 33 μ long. Band of scales, 2 to 4 μ wide.

Butler.(5)
Spores round or rarely elliptical, 20 to 24 μ in diameter.

Winkler.(23)
Spores rounded, 20 to 33 μ in diameter.

As shown by the measurements of different authors given in Table 1, the spores of *Tilletia horrida* are slightly variable in size. The range of variability was found by the writer to be as follows: Globose, 23.37 to 30.21 μ by 25.65 to 31.35 μ; and

the elongated, 21.66 to 31.35 μ by 26.79 to 35.34 μ. Taking the average of the two extremes, the globose spores are 26.79 to 28.5 μ and the elongated 26.5 to 31.06 μ. These measurements include the width of the peripheral band or spinous or scalelike, hyaline projections, approaching closely the measurements of Anderson,(1) which also include the hyaline band. By subtracting from these measurements the width of the hyaline band, they also conform with those of Takahashi.(21)

In Japan, Takahashi(21) observed the germination of spores in water in three days. According to this author, the short germ-tube, or promycelium, was septated at the tip (1 to 3 septa); and 10 to 20 filiform, curved sporidia (38 to 53 μ long) were borne terminally in clusters. On separation from the promycelium, the sporidia became 3- to 4-celled. No fusion of the sporidia was observed.

With the exception of the spore germination, in which negative results were obtained in all attempts, even with the use of different concentrations of nutrient media, all the other principal distinctive morphologic features of the fungus, as admirably described by Takahashi,(21) have been confirmed by the writer. Even without ascertaining the mode of spore germination as a basis for the separation of the two smut families, the writer firmly believes that the black-smut fungus found on rice in the Philippines is identical with the disease of rice caused by *Tilletia horrida* Tak.

TRANSMISSION OF THE DISEASE FROM SEED-BORNE SPORES

POT EXPERIMENTS

Rice plants attacked by this disease do not generally exhibit marked differences from healthy ones during growth, according to previous observers. In his investigation upon the black smut of rice, Anderson (1) found evidence of the fungus hyphæ in the stem tissues of infected plants and he thought it reasonable to assume that seedling infection took place from spores adhering on the outside of the grains. In an effort to test the transmissibility of the disease or its reproduction through the planting of infected seeds, fifty plump, germinable seeds of the Sipot variety, showing a light spore-load were selected, soaked in sterile water overnight, and then sown in sterilized soil of uniform character in pots. Thus the spores were sown with the seeds. Another fifty seeds selected from healthy panicles were treated similarly and sown in another sterilized pot of soil from the same source, on June 15, 1931. The pots were subjected to controlled

conditions in a glass-roofed greenhouse which gets sunlight and usually registers a higher air temperature than the open. Of the fifty smutted seeds sown, only thirty-six germinated, while fourteen of them failed to germinate, although two showed initial signs of growth. All the healthy seeds germinated and grew normally. Twenty-nine of the surviving young bunt-seedlings exhibited a sort of etiolated or pale yellowish condition of the older leaves (Plate VI, fig. 1) in the early stages of growth, while seven seedlings showed similar symptoms on the younger leaves. Severe stunting was also exhibited in diseased seedlings, while none of these symptoms appeared in the controls (Plate VI, fig. 2). This phenomenon is generally termed "grain (seedling) infection," or infection from seed-borne spores. The infection is brought about by the simultaneous germination of seeds and spores, the latter producing short basidia(3) (promycelia), which form clusters of elongated terminal basidiospores (sporidia), which in turn produce infection hyphæ that penetrate the soft and tender tissues of the newly sprouted seeds and grow with the host until the spores break out again. The effect of the disease on the growth of thirty-six seedlings in each pot are given in the measurements of single plants in Table 2. In comparison with seedlings produced from healthy seeds, the foliage showed no chlorotic condition; they were healthy and green in spite of the crowded condition of the plants.

TABLE 2.—*Comparing the growth of healthy and smutted rice seedlings*

	Height of seedlings produced from smutted seeds (centimeters)			Height of seedlings produced from sound seeds (centimeters)[a]		
	42.6	42.2	44.6	65.0	64.0	59.0
	43.0	40.0	43.3	63.7	55.8	62.3
	41.5	45.7	46.0	57.0	56.6	61.0
	51.0	43.8	41.8	66.0	55.5	67.1
	47.6	43.0	43.5	61.2	66.5	64.2
	45.0	46.1	36.0	60.0	59.5	60.0
	44.0	45.4	35.4	58.7	64.2	54.0
	43.0	42.2	38.2	59.6	57.5	55.7
	46.4	45.0	37.3	56.5	64.3	58.0
	45.0	41.0	38.5	54.8	60.0	56.0
	45.5	40.9	42.5	54.5	61.0	60.5
	41.8	47.0	38.0	61.0	55.3	62.0
Total	536.4	522.3	485.1	718.0	720.2	719.8
Grand total			1,543.8			2,158.0
Average height			42.88±0.3810			59.94±0.4114
Probable error of difference						17.06±0.5607

[a] Measurements were taken at random.

It will be seen from the preceding data that there was a significant reduction in height in the seedlings grown from slightly smutted seeds, due to disturbances caused by the fungus in the normal physiological processes. In spite of the crowded condi-

tion of seedlings grown from healthy seeds, they were much taller (Plate VI, fig. 2) the average height being 59.94 ± 0.4114 centimeters and that of the diseased seedlings (Plate VI, fig. 1) 42.88 ± 0.3810 centimeters, showing a significant difference of 17.06 ± 0.5607 centimeters. Due to reflected light from the glass roof of the greenhouse at the time of exposure, some of the leaves of the control seedlings (Plate VI, fig. 2) appear as to show signs of discoloration also.

Fifteen of the severally diseased seedlings were transplanted in the open in three large concrete pots containing the same quantity of sterilized, uniform soil and five healthy seedlings were transplanted in similar soil in another pot and used as a check. At maturity, October 3, 1931, the plants were photographed (Plate VII), and measurements of the height of all the plants were taken, the number of bearing culms produced were counted, and the grain yield was weighed, as shown in Table 3.

TABLE 3.—*A comparison of the general vigor and yield of plants grown from smutted and healthy seedlings*

[S, with smutted heads; O, no smutted heads; D, dead.]

Pot	Plant 1				Plant 2			
	Culms	Average height of tillers	Result	Grain yield	Culms	Average height of tillers	Result	Grain yield
		cm		*g*		*cm*		*g*
I	5	120.5	S	9.75	7	121.5	S	14.38
II	9	120.2	O	20.45	7	123.6	S	16.56
III	7	92.9	O	7.44	5	81.4	S	6.49
Check	12	137.8	O	27.30	8	136.6	O	26.97

Pot	Plant 3				Plant 4			
	Culms	Average height of tillers	Result	Grain yield	Culms	Average height of tillers	Result	Grain yield
		cm		*g*		*cm*		*g*
I	6	123.3	O	9.00	3	183.3	O	5.05
II	6	123.7	S	14.13	7	121.8	S	12.23
III	7	85.4	S	9.29	6	79.7	S	10.05
Check	9	143.0	O	19.35	12	134.1	O	30.85

Pot	Plant 5				Average number of culms per plant	Average height of plants	Average grain yield per plan
	Culms	Average height of tillers	Result	Grain yield			
		cm		*g*		*cm*	*g*
I	6	125.4	S	13.96	5.4	134.8	10.43
II	D	0.0	D	0.00	7.2	122.3	15.84
III	5	86.3	S	5.78	6.0	85.1	7.81
Average per pot	.....	.....	.....	.....	6.2	114.0	11.36
Check	12	142.0	O	21.31	10.6	138.7	25.15

Of the fifteen seedlings transplanted in relatively big pots, one perished due to the disease. A very interesting result of the experiment is that not all the diseased seedlings transplanted in the open developed smutty heads. Some of the heads apparently showed no trace of bunt infection, which may partly be accounted for by the presence of conditions unfavorable for fungus development during the early growth of the plants, so that the vegetative mycelium failed to ramify to all parts of the plant, the fungus filaments at the base reaching only the growing point of slow-growing plants. The receptivity of the individual plants in this case differs towards the smut fungus and even in the same material under similar conditions only a portion of the host plants became smutty. The number of spores present influences the resulting infection, as those situated on the embryo or its neighborhood have greater chances to cause infection than those more remote. This does not mean, however, that the diseased seedlings on maturity no longer harbor the parasite, but that the vegetative organs were feebly present and failed to reach the panicles before the maturity of the grains. But that infection is one of true systemic development, pervading the plant tissues, cannot be doubted. The control plants remained healthy.

An examination of Table 3 will reveal that the stunting effect of the disease on the growth of the plants was very evident at maturity; the diseased plants and the control plants being on the average 114.0 centimeters and 138.7 centimeters in height, respectively (Plate VII). Fewer tillers or bearing culms were produced in the diseased plants than in the healthy plants, or in round numbers, 6 against 10, respectively, per pot. With regard to grain yield, a considerable diminution was observed in the smutted plants; for while the diseased plants yield on the average 11.36 grams per plant, the healthy, control plants yielded 25.15 grams per plant, or 54.83 per cent more. Although these experiments were not as extensive as they should have been, they show that the disease undoubtedly produces stunting and a subsequent decrement in grain yield and in straw coincident with the production of typical black smut symptoms. Thus we may say that the experiments began with diseased seeds and ended in diseased seeds.

FIELD EXPERIMENTS

July 10, 1931, twenty-one of the diseased Sipot seedlings showing a milder degree of stunting and chlorotic effect than those

used in the pot experiment, and twenty-one of the healthy seedlings also sown in the greenhouse were transplanted singly, 20 centimeters apart in the row, in a lowland rice field where no smutty rice crop was grown. The check plants were transplanted some distance away, but they were given precisely the same treatment. In other words the plants were afforded ample room for development. At maturity the height of the plants was measured, and later the panicles of each plant were gathered and placed in separate paper bags. The results of this test are given in Table 4.

A study of Table 4 brings out the fact that sixteen of the plants grown from infected seedlings produced smutted plants and five plants were apparently normal. The computations given, however, were based on the number of smutted heads. On this basis a lower percentage of infection, or 1.39 per cent, resulted than would have occurred had the whole plant been used as a basis. Usually only one or two heads on the plant, and quite often only a few grains on the head, showed infection. A better appreciation, however, of the toll taken by the disease could be obtained by making a critical scrutiny of the stunting effect and grain yield. The smutted plants had an average height of 165.8 ± 1.0632 centimeters showing considerable stunting by a difference of 10.1 ± 2.8763 centimeters in the average height from that of the healthy plants which was 175.9 ± 2.6723 centimeters.

The panicles of each plant were threshed separately and weights were taken of the yield. The smutty plants gave an average of 72.6 ± 3.6950 grams and the normal plants 84.0 ± 4.8292 grams, showing a difference of 11.4 ± 6.0806 grams, or 12.8 per cent. As regards the grain yield in this case, the seedlings transplanted, to begin with, showed only mild symptoms of the black smut, with no severe effects, so that there was only a slight increase in favor of the normal plants over the diseased plants, or an average of 11.4 grams per plant. Five of the plants in the supposedly diseased plat were observed to be smut-free, as far as panicle examinations were concerned, which may be accounted for, presumably, by the favorable conditions obtaining for the host plant to outgrow or resist the progress of the fungus. The results seem to strengthen the previous observations that the season of planting appears to influence to a large measure the outbreak of the disease. As has been observed, dry-season planting seems to predispose the rice plants to this disease more than the wet-season planting does.

TABLE 4.—*Rice plants produced from smutty seedlings compared with those produced from disease-free seedlings*

Grown from smutty seedlings					Grown from smut-free seedlings				
Plant No.	Height at maturity	Heads	Smutty heads	Grain yield	Plant No.	Height at maturity	Heads	Infested heads	Grain yield
	cm			*g*		*cm*			*g*
1	171	30	4	119.7	1	210	45	0	184.7
2	162	22	5	110.0	2	171	20	0	97.6
3	146	14	2	35.9	3	163	17	0	70.7
4	163	16	2	82.4	4	166	19	0	74.9
5	168	20	3	63.7	5	196	23	0	103.9
6	172	25	3	88.6	6	202	21	0	113.3
7	175	17	2	48.0	7	203	21	0	63.2
8	178	21	4	84.9	8	163	13	0	53.2
9	162	20	5	102.9	9	192	15	0	59.2
10	169	14	1	42.9	10	203	14	0	57.3
11	176	24	0	99.8	11	161	26	0	81.5
12	168	13	2	47.6	12	166	21	0	83.2
13	158	14	2	83.6	13	167	33	0	115.6
14	157	20	3	65.2	14	165	22	0	81.8
15	163	24	2	98.1	15	155	44	0	163.9
16	159	11	0	32.6	16	200	26	0	87.0
17	166	24	0	80.3	17	167	21	0	79.9
18	170	25	0	81.0	18	160	23	0	80.0
19	171	24	1	81.2	19	161	20	0	76.2
20	165	29	4	69.0	20	160	16	0	71.2
21	163	26	0	108.4	21	164	15	0	66.9
Total	3,482	433	45	1,625.8	Total	3,695	475	0	1,865.2
Average	165.8	20.61	[a]1.39	72.6	Average	175.9	22.61	0	84.0
Probable error of mean	±1.0632			±3.6950		±2.6723			±4.8292
Probable error of difference						10.1±2.8763			11.4±6.0806

[a] Per cent infection.

July 10, 1931, one hundred Sipot seeds slightly coated with bunt spores, soaked previously in clean water, were sown in a rice seedbed at Alabang, Rizal Province. Another batch of one hundred seeds from bunt-free stock of the same year's crop was treated in the same way and sown in another seedbed. Transplanting of the seedlings was done August 24, 1931, singly in rows side by side, 20 centimeters apart, and spaced 20 centimeters in the row. At the time of maturity the heights of the plants in both plats were measured and later, when harvest time came, the number of panicles per plant were counted. The weight of the grains of each plant was taken. The data obtained from this experiment are shown in Table 5.

Here it is noted that although all the seeds sown bore spores on the outside, some of those which were able to germinate but were more resistant to the disease succumbed, while those which were more resistant survived. The number of seedlings produced was counted in each lot, and it was found that only 64 grew from the smut-spore-covered seeds while 94 seedlings developed from the healthy seeds. Despite the fact that all the seeds were sown in the same soil and transplanted alongside each other in similar soil, the plants were not equally infected and a number escaped infection, the vulnerable period being only of short duration. This suggests also the possibility that the infection thread had penetrated into the seedlings but failed to reach the growing point, which may also be accounted for by the variation in time of germination of the individual seeds.

Summarizing the data given in Table 5, another tabulation is here presented designated as Table 6, which shows quite significant figures obtained from the result of this experiment as regards the heights of plants, but not so with the grain yield.

It will be seen in Table 5 that only a few of the plants produced from smutted seeds showed considerable stunting. In order, however, to be able to make a fair comparative study of the result of the test only an equal number of plants in the healthy plat were observed, and it was found (Table 6) that the diseased plants had a mean height of 141.80 ± 1.1382 centimeters and the healthy plants 149.92 ± 0.8511, centimeters or a difference of 8.12 ± 1.4212 centimeters.

On examining the panicles from the diseased plant (Table 5) only 28 panicles, or 5.98 per cent were found smutty. In every case there was a mixture of smutted and disease-free panicles in the same plant. Even infected plants were only partially bunted and there was a greater proportion of sound than of

TABLE 5.—*A comparison of the growth, number of panicles, and grain yield of rice plants grown from smutty and normal seed*

Grown from smutty seeds				Grown from normal seeds			
Height of plant	Panicles	Panicles infected	Grain yield	Height of plant	Panicles	Panicles infected	Grain yield
cm			*g*	*cm*			*g*
138	12	1	30.0	151	6	1	20.5
147	16	0	40.5	145	6	0	17.0
149	7	1	22.5	148	5	0	20.0
144	6	0	20.0	146	5	0	13.0
88	0	0	0.0	145	6	1	18.0
146	11	2	30.0	140	5	1	14.0
152	14	1	39.5	153	7	0	20.0
147	15	0	54.5	155	18	0	22.0
78	0	0	0.0	165	7	0	17.0
148	9	2	21.5	142	7	0	23.0
153	11	2	31.0	142	9	1	4.0
150	14	0	29.0	150	5	0	17.5
149	8	1	31.5	136	0	0	0.0
145	9	2	30.0	149	8	0	13.0
149	15	0	35.0	152	6	1	14.0
148	12	1	37.0	139	6	0	10.0
146	9	0	28.0	143	4	0	6.5
149	8	0	19.0	151	3	0	7.0
152	11	1	30.5	152	3	0	12.5
136	16	0	45.0	151	6	0	16.5
137	11	0	36.0	154	5	0	15.0
143	8	0	21.0	143	4	0	12.5
146	5	2	8.0	147	5	1	10.2
150	4	1	13.0	152	5	3	18.0
144	6	0	23.0	148	5	1	19.0
139	4	0	11.5	146	8	0	8.0
143	6	0	19.5	152	4	0	10.7
143	8	0	26.0	153	10	0	29.0
106	7	0	25.0	154	10	0	15.0
141	7	1	15.5	138	6	0	13.5
148	3	0	12.5	137	3	0	4.5
149	6	0	20.0	130	3	0	7.5
164	19	0	52.0	154	5	0	16.0
140	12	0	35.5	144	7	0	15.0
143	14	0	43.5	153	4	0	11.0
151	14	0	40.0	158	5	0	13.7
156	11	0	34.5	147	5	0	12.5
143	9	0	27.0	147	5	0	13.7
145	11	0	32.0	187	6	0	29.0
149	11	0	29.0	142	11	0	29.0
157	13	0	38.0	158	8	0	25.0
151	13	0	39.5	158	13	0	40.0
144	9	0	22.5	155	8	0	24.5
145	8	0	21.5	165	6	0	16.5
141	13	0	36.5	173	4	0	11.0
143	5	0	12.5	147	4	0	10.0
140	9	0	24.0	152	4	0	12.0
144	7	0	16.7	148	7	0	16.7
141	8	0	23.0	147	5	0	13.0
145	8	0	17.7	143	5	0	12.5
174	6	0	20.7	149	7	0	14.5
140	18	0	44.7	154	4	0	9.0
192	8	0	29.0	151	6	0	16.5
156	8	0	20.5	145	8	0	23.0
150	6	0	14.5	159	4	0	8.0
151	7	0	16.5	151	13	0	40.0
147	7	0	18.5	150	3	0	8.0
151	7	0	14.5	152	5	0	13.0
158	5	0	14.7	150	6	0	15.0
142	4	0	10.5	155	11	0	32.7
172	6	0	15.7	150	7	0	20.7
144	9	0	16.5	144	5	0	10.7
150	4	0	8.2	159	2	0	3.0
152	7	0	20.0	154	4	0	6.0

diseased stalks. In three plants the growth of culms as well as the development of heads was somewhat arrested and when maturity was reached heading was presumably much delayed, so that there are no grain yields given.

TABLE 6.—*Summary of Table 5*

Material	Plants	Mean height	Mean yield	Difference in height	Probable error of difference	Difference in yield	Probable error of difference
		cm	*g*	*cm*		*g*	
Diseased....	64	141.80±1.1382	17.73±0.9394	.....	.....	.....	.....
Control.....	64	149.92±0.8511	18.90±0.9295	8.12	±1.4212	1.17	+1.3215

In grain yield (Table 6) there was a slight difference of 1.17 ± 1.3215 grams, the diseased plants, producing an average of 17.73 ± 0.9394 grams and the healthy plants 18.90 ± 0.9295 grams. The smutted plants as a whole produced a slightly lesser number of bearing culms; and the heads were somewhat lighter than the normal heads, in some instances. The decrease in grain yield may be explained by the fact that even when the straw is fully developed, the grains may be poor because the needs of the fungus have to be provided for as well as those of the host plant.

An important fact is here brought out and made more evident, that is, that a certain degree of heat is invariably indispensable for the proper development of the organism as well as other conditions that of necessity must prevail simultaneously in order to produce successful infection. And it has been observed in the field that rice plantings at the outset of the summer months were more readily affected by the disease than those grown during the rainy season, which theory seems to have been borne out by sowings made inside a glasshouse and those made in the open where the temperature varied in the two environmental conditions. In other words the proper season of the year is essential for the germination of the spores, which seems to be stimulated also by a high temperature.

HISTOLOGICAL EVIDENCE

That the black smut of rice is systemic is unquestionable and so we would naturally expect a certain host response, such as a disturbance of its normal physiological function. Seedlings grown from slightly infected seeds producing seedlings exhibiting a kind of pallor on the leaves developed black smut in the grains on maturity. No attempt was made to make a histological study of the tissues of smutted plants, but from the conditions of the experiment there is every reason to believe that the etio-

lated and stunted condition of seedlings produced from slightly smutted grains proved that the fungus is present in such host tissues, gaining entrance during early growth. As cited by Stevens(19)[5] "cross section of stems bearing smutted heads reveal the mycelium in the chlorophyll perenchyma between the fibrous tissue." The findings of Anderson(1) convincingly show the mode of infection of the stem tissues. Eight inches (20 centimeters) below the panicles of the infected plant, the stem showed, in cross and longitudinal sections, the presence of a mycelium very similar to the diametrically larger mycelium found associated with spores in the ovary. It is claimed this is present only in the subepidermal vertical rows of loose chlorophyll parenchyma, which lie beneath the rows of stomata in the epidermis." None was found in the stereome, nor in the vascular bundles and colorless parenchyma in the inside of the culm. It seems probable that the chlorotic appearance of some seedlings seriously affected was due to this internal invasion. Sections of the rachis showed similar mycelium.

FACTORS INFLUENCING DEVELOPMENT

There are certain ecologic conditions which predispose rice to bunt and due to these conditions the degree of smutting fluctuates. According to observations, rains followed by hot sunshine immediately after sowing are conducive to its rapid development as the emerging seedlings are at once exposed to the possibility of infection. But this is also influenced by the host susceptibility and by the abundance of smut spores present in the soil or on the seed. It seems probable that excessively damp soil or impermeable soil continuously under water during the entire growing period of the plants are also contributory agencies. Field observations seem to indicate that susceptibility is more pronounced when planting is done in "palagad," or during the dry season, under irrigated conditions, than in the regular rice season, probably due to the prevalence of hot weather and the presence of abundant stagnant water or artificial irrigation. That the intensity of attack by this disease varies from year to year and even in the same variety of rice seems to confirm the writer's belief that weather or some other environmental condition has really a certain relation to the occurrence of the disease. As with members of this group of fungi it multiplies rapidly when favorable conditions obtain. In the

[5] Anderson, A. P., South Carolina Bull. 41 (1899).

studies of Appel and Riehm, as cited by Woolman and Humphrey,(24) these authors have consistently shown that tilletia grows readily enough in the soil, probably due to the presence of organic flora.

DISSEMINATION

The fungus is undoubtedly distributed in nature most extensively by spores adherent to the outside of the grains and by those produced within the graims. The disease is transmitted to the succeeding crop by planting infected grains, or grains with spores adhering to them, for when the grains germinate by reason of a certain unknown stimulus, the spores germinate also and the germ-tubes infect the rice seedlings. Slight infections are difficult to detect and by subsequent inadvertent planting the infection may be increased.

As with other cereal smut disease, soil infection seems highly probable which facilitates disease transmission from crop to crop. It may also be possible that the spores are carried by the wind from diseased heads to healthy ones, especially when varieties of rice maturing at different periods are grown.

The spread of the disease is generally brought about when sound and infected panicles are harvested and mixed together in the threshing. The danger of sound grains becoming contaminated with the millions of spores in heavily smutted grains smashed by threshing operations is great and it should be realized that each individual spore discharged and scattered is capable of reproducing the disease. The sticky bunt spores, which usually adhere to the hairy portions of the glumes of germinable seeds, may germinate when the seeds are sown and in this way the disease be carried or propagated from crop to crop. Burst grains or grains with tips forced apart, or with spurlike outgrowths due to bunt infection expose the mass of spores within and spores dissipated by the wind may lodge on the grains of healthy plants, which when planted later may cause subsequent infection. This adequately explains the source of infection in succeeding crops. The spores being very sticky adhere readily to many objects they come in contact with and are thus dispersed.

The possibility of soil infestation through the falling off of bunted grains or panicles to the soil, especially during harvest time is great. Spores blown by the wind may be scattered on the ground. The disease may also be spread by infected implements, bags or sacks, winnowing machines or by other mechanical means.

As the spores develop under the cuticle of the grain consisting of the wall of the ovary and the outer layers of the true seed, and as this outer covering is removed in milling and comprises a great part of the rice bran, it can be easily seen how smutted grains contaminate this by-product of rice as well as flour. When infected rice or bran is fed to fowls, hogs, cattle, horses and other animals, and the viability of the spores is retained or not in any way injured or decreased after passing through the digestive tracts of such animals, the spores contained in their manure are thus in danger of being scattered .

When varieties maturing at different periods are planted in the same field or in close proximity with each other, the chances of infection from an infected variety to an uninfected one by contact with aërial spores is likely to occur. Fulton,(11) Copeland,(7) and Mackie(15) think the flower-infection phenomenon a probability but they have no evidence to support it.

ARTIFICIAL INFECTION OF RICE PANICLES WITH THE BLACK-SMUT SPORES

Infection through the flower has been carefully demonstrated by experiments with other cereal smuts. With rice bunt, however, although certain authorities believe it takes place in nature, no experiment has been made, as far as the writer is aware. This experiment, therefore, was conducted in an attempt to reproduce the black smut through the use of spores by spraying them on the panicles. Normal rice panicles of the Sipot variety at different stages of development were sprayed with smut spores dispersed in water; (*a*) on emerging inflorescences, (*b*) during the blossoming period, (*c*) at the milk stage, (*d*) at the dough stage, and (*e*) on maturing panicles. The spraying treatment was the same, an atomizer being used in order to secure a fine mist that would adhere readily to the surface of the sprayed panicles at the same time making a uniform distribution of the spores, and then the sprayed panicles were immediately covered with paper bags. An equal number of plants with their panicles in the same stages of development were sprayed at the same time with blank sterile water and bagged likewise to serve as controls. Spraying was all done early in the morning, and on the supposition that the spores would germinate on the moist surface of the panicles. Following the examination, both macroscopically and microscopically, of the sprayed and unsprayed panicles, the details were carefully noted and are shown in Table 7.

TABLE 7.—*Artificial infection of normal rice panicles at different stages of development by spraying with spores in water suspension*

Stage of development of panicle	Date sprayed	Stools	Panicles	Panicles infected	Remarks
Sprayed					
1. Emergence of panicle	Sept. 28, 1931	4	4–6–6–6	0	Trace of inoculum on hull.
2. Flower stage [a]	Oct. 9, 1931	4	5–4–5–6	0	
3. Milk stage	Oct. 16, 1931	4	5–5–5–5	0	Spores found on hull.
4. Dough stage	Oct. 23, 1931	4	5–5–5–5	0	
5. Maturing	Oct. 30, 1931	4	5–5–5–5	0	
Check					
1. Emergence of panicle	Sept. 28, 1931	4	5–5–5–6	0	
2. Flower stage [a]	Oct. 9, 1931	4	5–5–5–5	0	
3. Milk stage	Oct. 16, 1931	4	5–5–5–5	0	
4. Dough stage	Oct. 23, 1931	4	5–5–5–5	0	
5. Maturing	Oct. 30, 1931	4	5–5–5–5	0	

[a] The flowers were yet closed when spraying was done.

As will be seen from Table 7, mature spore infection seems to show the futility of trying to reproduce the disease by spraying panicles with spores in suspension. After harvest all the panicles so treated were examined with the aid of a magnifier but none of them exhibited any sign of the disease. In a few panicles, however, as in stages 1 and 3, some dark spores typical of the black smut were detected on the glumes but these showed no indication of germination as confirmed by microscopic examinations.

How the spores can find their seedbeds when the flowers are closed and protected by the glumes is really something to wonder about. But the reason for these negative results might be explained by one or two possible factors; first, that the most favorable period was not exactly hit and, second, that the technic was not precisely the correct one to follow. Also, spores from natural host plants when transferred to pure water might have received some injury which resulted in their death or weakened development. It is believed that the infection of panicles can only occur during the receptive stage of the flower, or before the incipient formative state of the ovary, as it is possible that the germ-tube may find its way into the developing ovary. It is not known what success would be obtained if spores were sprayed on the stigma of open flowers or by putting spores on the walls of the nascent ovaries, as no test has been made to demonstrate the effects of these methods. On account of its practical importance, and as these trials are not extensive enough, flower infection under almost natural conditions should be tested by further experiments.

The panicles bagged during the early periods of panicle development, stages 1 and 2, produced a considerable percentage of chaffy grains indicating the detrimental effects on grain formation of covering the panicles with paper bags even if the bags are loosely tied at the base. For the same reason the writer entertains the belief that bagging probably causes certain injurious effects on the germination of the black smut spores.

VARIETAL SUSCEPTIBILITY

Field experience has shown that varieties seem to differ to a certain degree in their liability to the disease. The early varieties, perhaps because of the coincidence of warm, moist weather at the time of the ripening of the panicles apparently showed more susceptibility than the late varieties. "Palagad," or dry-season rice varieties like Sipot, for instance, have been observed to be easily attacked by the black smut. Guinangang Str. 1 and Apostol, two other early-maturing varieties, also showed slight susceptibility, while Mancasar Str. 3 appeared to be comparatively resistant. Elon-elon was unaffected, apparently. Seasonal conditions seem to influence greatly the reaction of the varieties towards the disease. On account, however, of the meager observations made in the field by the writer, the data on relative susceptibility of varieties to the disease is necessarily provisional.

In Louisiana,(11) red rice and Honduras especially the latter were reported susceptible to it, and certain rice millers claimed to have seen it, but rarely, on Japanese rice. In India,(5) its sporadic outbreaks show no respect for any particular variety.

While the rice bunt is a grain-infesting disease, it thrives well on the starchy portion or water absorbing constituent of the kernel, and seems more prevalent on varieties having a more or less chalky endosperm, characterized generally by the presence of a big white belly, or white opaque area in the center, it seems interesting to find what connection, if any, the disease has on the texture or major constituents of the kernel, in such varieties as those having a somewhat translucent, flinty or corneous endosperm, like Elon-elon, for example, and those which are partly chalky and brittle, like Sipot, or those uniformly chalky and opaque. In the absence of analysis as to the quantitative difference of these constituents in the types of kernels described, it is premature to state anything as to their possible relationship with the black smut fungus.

The viability of the seeds of the different varieties seems also a limiting factor in the prevalence of smut, as those which germinate rapidly would likely outgrow the effects of the fungus.

The difference in succulence in the stems of varieties might have also some relation with their resistance or susceptibility, as the less sappy varieties would probably retard, if not inhibit altogether the entrance and normal development of the pathogene. And just how upland rice would react to this disease nothing definite is yet known.

PREVENTIVE OR CONTROL MEASURES

While the disease is not considered at present of major importance, as its distribution and prevalence in the Philippines is not definitely known, it seems advisable to have some sort of remedy at hand which can be resorted to should the necessity arise. As with almost any harmful and disastrous thing under the sun, the problem lies not so much in combating the disease as in preventing it, to do which certain steps may be suggested.

To control the disease effectively, one needs to be familiar with its symptoms and signs. Familiarity with the disease is an important consideration because the disease is not easily detected in the field and may be confused with other grain diseases. It is also important to have a knowledge of the mode of infection and the factors favoring it, as well as the cause, and the agencies of dissemination.

Without going into details, the principal preventive measures may be summarized as follows:

As the disease is carried by the seeds attention cannot be too strongly directed towards the careful selection of seeds derived from healthy plants. As far as possible, procure seeds from a healthy crop or from a locality where the disease is not known, taking care not to contaminate the selected seeds through the use of threshing machines, sacks or other containers. It is always advantageous to sow well-developed, smut-free grains, as they will produce the best plants, and before sowing, always to remove chaffy or light grains, weed seeds and other foreign materials. Besides, this will save any extra outlay for fungicides, or for more seeds to the hectare due to decreased rate of germination and may be for re-sowing.

Another means of control that might offer considerable promise at present would be local quarantine, or prohibiting the export of seeds from infected localities, with thorough inspec-

tion and treatment of seeds for planting purposes to obviate the risk of disseminating the disease, and to prevent its development in large areas.

As infection apparently takes place during the early stages of seed germination, the application of formalin, that is, 1 part formalin to 50 parts water at the rate of 2 quarts (1 quart equals 946.5 cubic centimeters) per square foot of soil, to the seedbeds a week or more before seeding would probably be beneficial also.

In serious infections, or if no sound seeds are available, the infected grains should be separated from uninfected ones by pouring them into water portion by portion, stirring vigorously so as to float the lighter, infected grains which should then be skimmed off. The wet grains should be spread thinly and dried in the air at once, and should not be used for seed. To insure that no traces of the smut are left in the seeds, it is better to treat them with one of the recommended fungicides before sowing.

Rice seeds with spores adhering to the glumes may be disinfected. In South Carolina,(11) where it is claimed the rice bunt was stamped out in four years after its appearance, the treatment followed was pouring the infected grains into water and skimming off the floating or light grains and then soaking the seeds for a day, or for twenty-four hours in a solution of 1.5 pounds of liver of sulphur (potassium sulphide) in 25 gallons of water, or soaking for two hours in a 2 per cent solution. Owing to the close similarity of this disease to the wheat bunt, it is probably amenable to seed treatments that have proved successful for the prevention of the latter, such as the copper carbonate dust treatment, formaldehyde treatment, and the use of ceresan, dubay, semesan, or various other organic mercury compounds on the market. But these chemical treatments are not recommended universally, except in serious infections, for they are expensive and have to be given every year; irksome, because of the difficulties involved in handling; and highly poisonous. Seeds treated with these chemicals should not be used for food because they are poisonous. Haskell et al.,(12) in connection with wheat bunt, recommended the following seed treatments:

Copper carbonate dust treatment.—Use 2 ounces (1 ounce equals 28.3495 grams) of 50 per cent grade or 3 ounces of 18 to 20 per cent grade applied to each bushel (equals 35.2 liters) of seed with a home-made revolving barrel duster. See to it that all the seeds are covered completely by the dust.

Formaldehyde treatment.—Soak the seeds in a solution made up of 1 pint (equals 0.473 liter) commercial formaldehyde to 40 gallons (1 gallon equals 3.785 liters) of water, no more and no less, using containers that will float the light infected grains to the surface where they can be skimmed off. Formalin-treated seeds should be sown immediately in wet soil. Care should be taken that no reinfection takes place after treatment.

Organic mercury compounds.—Uspulun or germisan 0.25 per cent solution for thirty minutes, which afforded effective control of wheat bunt, according to Heald,(13) may also be employed. These modern compounds of organic mercury should prove wonders as seed disinfectants as they are generally considered to give perfect protection and at the same time maintain the vitality of the seeds and stimulate the growth of the seedling.

Seed treatments, however, although generally effective are of no avail if the details are not followed carefully and persistently. Suitable equipment and reliable chemicals are also necessary adjuncts.

Caution.—These chemicals are poisonous and have to be handled with great care; besides, formalin irritates the eyes. No treated seeds should be used for food or fed to animals. When using copper carbonate, a dust mask should be worn by the operator.

The hot-water treatment is another method of destroying seed-borne organisms, but it is tiresome and likely to fail unless the temperature recommended is kept constant. Smutty seeds are dipped in hot water at 53° C. for ten minutes, or 54° C. for five minutes, if the seeds were soaked previously in water for a day. Hot water destroys the spores of all smut diseases, but if the directions are not adhered to closely it may injure the seed and the percentage of seed germination may be lowered.

And while seed treatment is effective and a recommended practice, it does not totally shield the plants from being attacked through infected soil; which makes the growing of resistant varieties or strains having commercial importance, or attractive culinary qualities,(6) advisable. This is the cheapest method and usually gives more lasting results, as one does not have to give tedious treatments year after year, unless the stability of the organism changes; that is, unless the problem is complicated by the production of the so-called physiologic forms.

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[6] The best index for their merits in the rice trade, but this is generally regarded as a secondary consideration in rice production.

To prevent the probable occurrence of alternate hosts, clean culture should be the rule.

Rice should not be followed by rice in fields where the black smut occurred the preceding year. To do so is to invite loss. How long the period of cropping should last is not definitely known and therefore no general recommendation can be given.

It is not safe to feed bunted rice to animals, such as fowls, pigs, etc., even though it may have little or no ill effect on them, because they are liable to scatter the spores to non-infected fields.

SUMMARY

The black smut, or bunt, of rice seems to have been introduced from Japan through the importation of seed rice, and its actual appearance in the Philippines is here reported for the first time. Although an article on rice diseases appeared in print in 1926, this was a compilation only and the circular on the subject was intended mainly as a warning to Philippine rice growers.

The disease is present in many important rice-producing countries of the world. Its distribution in the Philippines is not definitely known, as no systematic survey has yet been made. It is not considered a serious disease of rice, yet at times it is capable of causing considerable damage. It not only has a retarding influence on the growth and a pronounced effect on the yield but also may reduce the quality or lower the market value of rice.

The disease is not readily recognized in the field and can only be detected when the panicles mature by the presence of black spores usually massed towards the tips of the grains. The blackened grains are distributed irregularly either singly or in groups among normal grains. Occasionally some of the infected grains show slight enlargement or separation of the tips. In exceptional cases a sort of beaklike or inverted spurlike structure may be seen extruded through rupture on the keel of the larger glume or lemma, a characteristic feature which heretofore has not been observed in connection with rice bunt.

Internally the affected grains are partly or wholly replaced by a sooty-black, pulverulent mass of spores, covered with a saclike, semi-transparent cuticle. This is the surest indication of the disease.

The gross symptoms as a result of field and laboratory observations, as well as the distinctive characteristic features of the causative fungus have been described in detail and illustrated. Morphologic examinations revealed that the spores are almost

exactly like those described by other authors with respect to color, size, shape, and surface characters. The conclusion is therefore drawn that the black smut fungus found on rice in the Philippines is identical with *Tilletia horrida* Tak.

Under controlled conditions the disease was reproduced from seed-borne spores. Infection took place apparently in the early stage of seedling development. When infected seeds were planted, on germination the infection threads penetrated the tissues of the young shoot and grew upward with the vegetative tissues of the host. Usually the disease causes slight interruption in the host cells that no external signs become perceptible, but that this disease is systemic cannot be doubted.

It is clear from the results obtained that black smut infection may cause the shortening of the culms of rice, manifesting itself at an early stage of development of the plant and a subsequent reduction in grain yield and in straw. It has not been possible, however, to determine definitely what reaction it would have under different environmental conditions and on other host varieties.

The virulence of the disease is especially dependent upon climatic and other environmental factors. Under favorable conditions the degree of infection is materially increased, while under adverse conditions even plants from infected seed may escape the disease.

Field observations seem to indicate that the time of planting influences bunt infection. There is sufficient observational evidence to substantiate this point, showing that susceptibility is more pronounced when rice is planted during the dry season under irrigated conditions than in the regular rice season, which is probably accounted for by the temperature and moisture conditions which normally prevail during summer.

The disease is seed-borne by adherent spores on the outside of the grains and by those produced within the grains. It is spread by soil infection, by planting spore-bearing seeds, and by the mixing together of diseased and disease-free seed in the threshing or in winnowing. Spores may be scattered by the use of contaminated bags, sacks or other containers, by contact of diseased and healthy panicles while yet in the field, by the agency of the wind, perhaps, and by contaminated bran or rice which has been fed to farm animals, such as pigs, fowls, etc.

Artificial infection of rice panicles at different stages of development proved futile but further experiments simulating natural conditions seem in order.

The disease has thus far been found only on irrigated rice. Varieties seem to differ to some extent in their liability to it; the early varieties, especially when planted during the dry season have shown more susceptibility than the late varieties. There seems to be a relation between the disease and the rice kernels having an opaque, chalky or brittle endosperm and those having a translucent, corneous or flinty endosperm.

The viability of the seeds of different varieties seems also a limiting factor in the prevalence of smut, as those which germinate rapidly would likely outgrow the effects of the fungus.

The per cent of smut appearing in the crop is influenced by various cultural practices, but great importance is to be given to the time or season of planting.

The control measures for the disease are discussed.

LITERATURE CITED

1. Anderson, A. P. A new Tilletia parasitic on Oryza sativa Linn. Bot. Gaz. 27 (June, 1899) 6, 467–472.
2. Anderson, A. P. Tilletia horrida Tak. on rice plant in South Carolina. Bull. Torrey Bot. Club 29 (January, 1902) 1, 35–36.
3. Brooks, F. T. Plant Diseases. Oxford University Press (1928) vi + 386.
4. Butler, E. J. Diseases of rice. Pusa Agr. Research Inst. Bull. 34 (1913).
5. Butler, E. J. Fungi and Disease in Plants. Thacker, Spink and Co., Calcutta (1918) iv + 547.
6. Cook, M. T. Diseases of Tropical Plants. Macmillan and Co., Ltd., London (1913) xi + 317.
7. Copeland, E. B. Rice (with a chapter on diseases and pests). Macmillan and Co., Ltd., London (1924) xiv + 352.
8. Duport, L. Notes sur quelques maladies et ennemis des plantes cultivées en extrême-orient. Bull. Econom. de l'Indochine 14 (1912) 99, 781–803.
9. Earle, F. S. A new Tilletia on Oryza. Bot. Gaz. 28 (August, 1899) 138.
10. Filter, P. Über das Vorkommen von Tilletia horrida Tak. in Reisfuttermehlen. Cent. für Bakter. etc. 29, 2 Abt. (1911) 342–346.
11. Fulton, H. R. Diseases affecting rice in Louisiana. Louisiana Agr. Exp. Sta. Bull. 105 (1908).
12. Haskell, R. J., R. W. Leukel, and E. G. Boerner. Stinking smut (bunt) in wheat and how to prevent it. U. S. Dept. Agr. Circ. 182 (September, 1931).

13. Heald, F. D. Manual of Plant Diseases. McGraw-Hill Book Co., Inc., New York (1926) xiii + 891.
14. Kirby, R. S., and W. A. Archer. Diseases of cereal and forage crops in the United States in 1926. Plant Disease Reporter, Supp. 53 (1927) 110–208; 4 graphs, 15 maps.
15. Mackie, W. W. Diseases of grain and their control. Calif. Agr. Exp. Sta. Bull. 511 (1931).
16. Miyake, I. Studien über die Pilze der Reispflanze in Japan. Journ. Coll. Agr. Tokyo Imperial Univ. Japan 2 (1910) 4, 237–270.
17. Rhind, D. Annual report of the mycologist, Burma, for the year ending the 30th of June, 1925 (1926) 5 pp. *Cited in* Rev. App. Myc. 5 (1926) 6, 344–345.
18. Seymour, A. B. Host Index of the Fungi of North America. Harvard University Press, Cambridge, Mass. (1929) xiii + 732.
19. Stevens, F. L. The Fungi Which Cause Plant Disease. Macmillan and Co., New York (1913) viii + 754.
20. Stevenson, John A. Foreign Plant Diseases. (A manual of foreign plant diseases which are new to or not widely distributed in the United States.) Washington, D. C., Government Printing Office (1926).
21. Takahashi, Y. On Ustilago virens Cooke and a new species of Tilletia parasitic on rice-plant. Tokyo Bot. Mag. 10 (1896) 109, 16–20, figs. 9–10.
22. Vincens, F. Rapport sommaire sur les Travaux effectués au Laboratoire de Phytopathologie de l'Institut Scientifique de l'Indochine du 1er Janvier 1919 au 1er Juillet 1921. Bull. Agr. l'Institut Scientifique de Saigon 3e Annee (Octobre, 1921) 10, 307–323.
23. Winkler, H. Die Schädlinge und Krankheiten des Reises. (The pests and diseases of rice.) Der Tropenflanzer 28 (1925) 4, 174–189; 242–255. Diseases of rice. Malayan Agr. Journ. 15 (1927) 87–96.
24. Woolman, H. M., and H. B. Humphrey. Summary of literature on bunt, or stinking smut of wheat. U. S. Dept. Agr. Dept. Bull. 1210 (1924).

ILLUSTRATIONS

Plate I

Rice spikelets affected with black smut caused by *Tilletia horrida* Tak. At the bottom are a few normal grains on the upper portions of the spikelets. About × 7/8.

Plate II

Portions of rice panicles showing conspicuous deformity of the grains as a result of serious black-smut infection. Note the inverted spurlike structure extruded by the bursting of the keel of the lemma or larger glume. Approximately × 2.

Plate III

Enlarged view of diseased and normal rice grains of same variety. Rows *a* and *b*, grains and kernels almost thoroughly blackened with spores and larger than the normal, showing the spurlike outgrowth; row *c*, smutted grains with the lemma removed, showing more or less varying degrees of infection; row *d*, infected grains with the apices forced slightly apart by hypertrophied ovaries; rows *e* and *f*, kernels exhibiting varying degrees of infection and the black masses of spores visible through the thin membrane of shriveled ovaries; and rows *g* and *h*, normal grains and kernels. About × 2.3.

Plate IV

[Camera-lucida drawings by the author × 876]

Fig. 1. Immature, hyaline spores of *Tilletia horrida* showing shrunken condition or irregularity of shape and arrested development due to overcrowding or to lack of nutriment.

2. Young hyaline spores showing peripheral thickening, remains of sporulating hyphae, and granular cell contents.

3. A hyaline spore showing no contents or spinous wall-projections.

4. A subhyaline spore showing the arrangement of rudimentary, blunt wall-projections and their reticulous formation. The interspaces between the spinous projections are clear and the projections are somewhate opaque.

5. Older spores, less opaque and yellowish when seen through transmitted light, showing well defined peripheral projections. Note that one of the spores still show the gelatinous envelope and the short remains of sporulating hypha.

6. *a*, A mature, opaque, dark-colored spore; *b*, bits of hyaline mycelium found mixed with spores; *c*, pieces of brownish, septate fungus filaments also found mixed with them.

Plate V

Fig. 1. A photomicrograph of spores of *Tilletia horrida* to show different stages of development. The surface appears tuberculate but actually the reticulate markings are the irregularly polygonal bases of the spinelike protuberances. The smooth-walled spores are hyaline and immature and the light-colored spores are yellowish maturing spores. Note the curved spinous projections. Surface view, × 380.

2. Sectional view of same spores photomicrographed to show clear outlines or echinulations or numerous curved projections from the epispore. About × 390.

Plate VI

Fig. 1. Twenty-five-day old rice seedlings produced from plump or lightly bunted seeds, showing marked evidence of dwarfing and chlorotic or pallid condition of the leaves.

2. Rice seedlings of same age photographed immediately after the smutted plants were taken, at same focal distance. Note that these healthy seedlings grown from healthy seeds, despite crowded condition, proved fast growers. The reflected light at the time of photographing spoiled somewhat the picture as if chloritic leaves were also present, although there was absolutely no evidence of it.

Plate VII

The three pots to the left contain maturing plants transplanted from seedlings obtained from the infected pot shown in Plate VI, fig. 1. Note the stunting of the plants in these pots in contrast with the plants produced from normal seedlings shown in the pot at the extreme right.

PLATE I

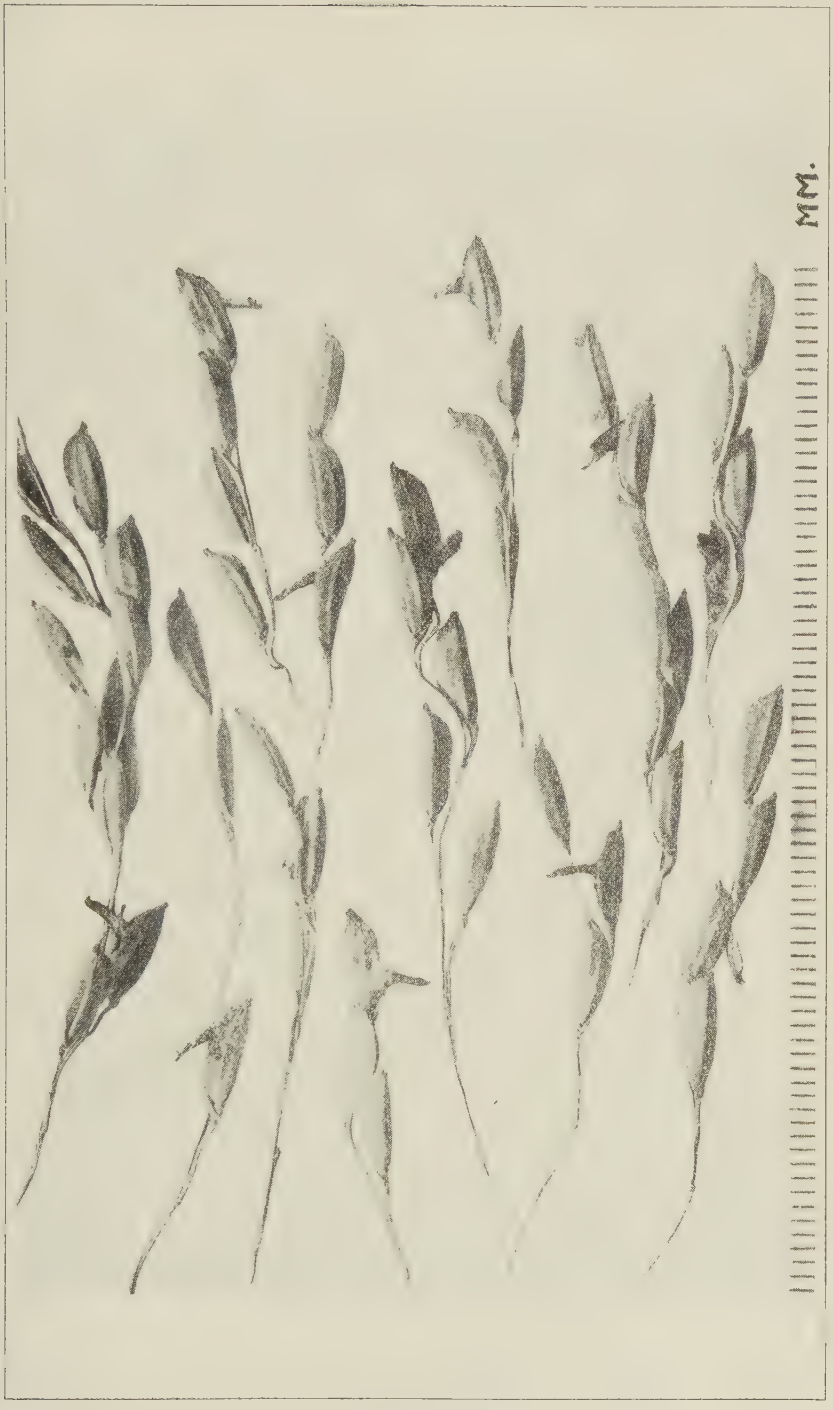


PLATE II

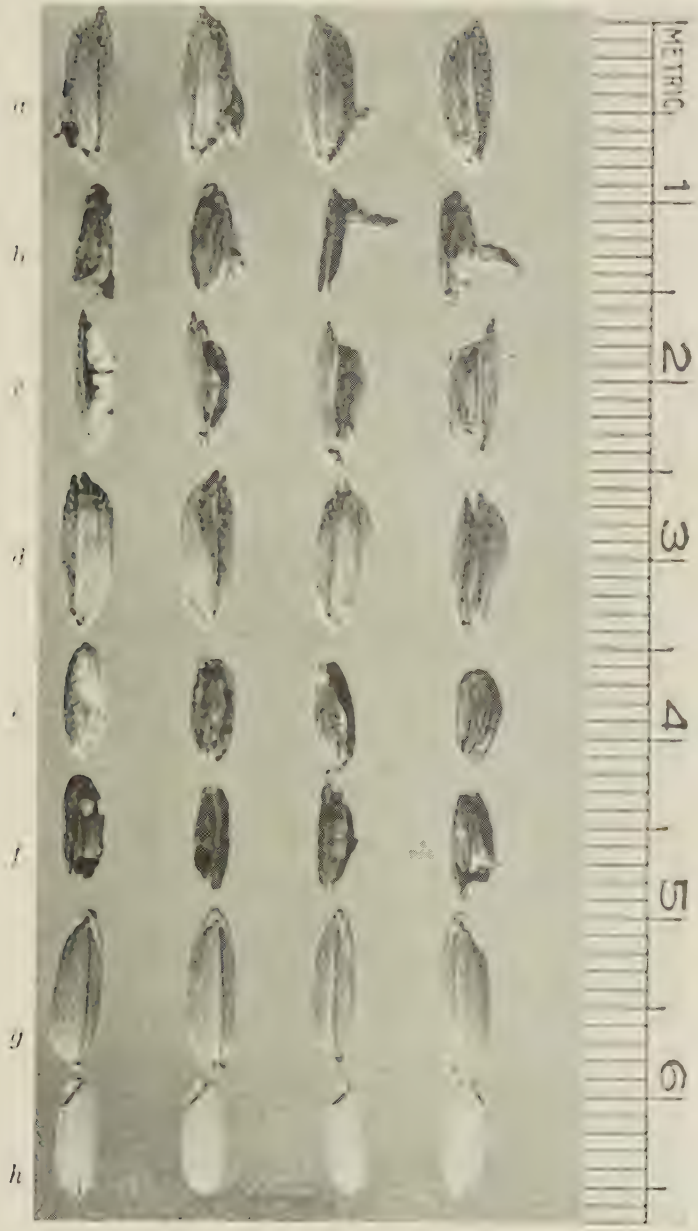
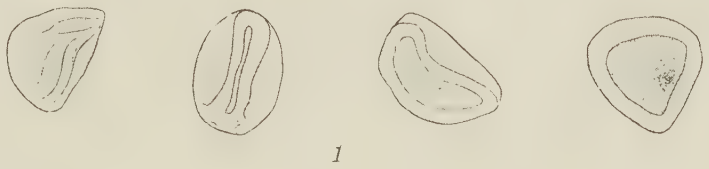


PLATE III



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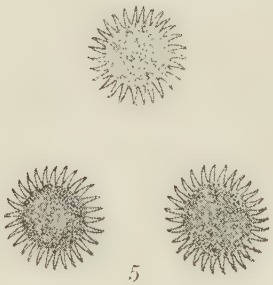

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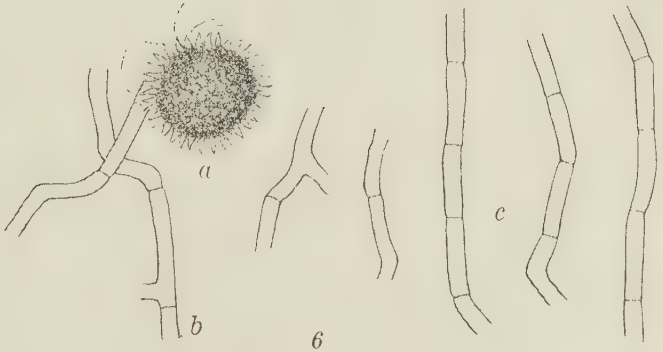

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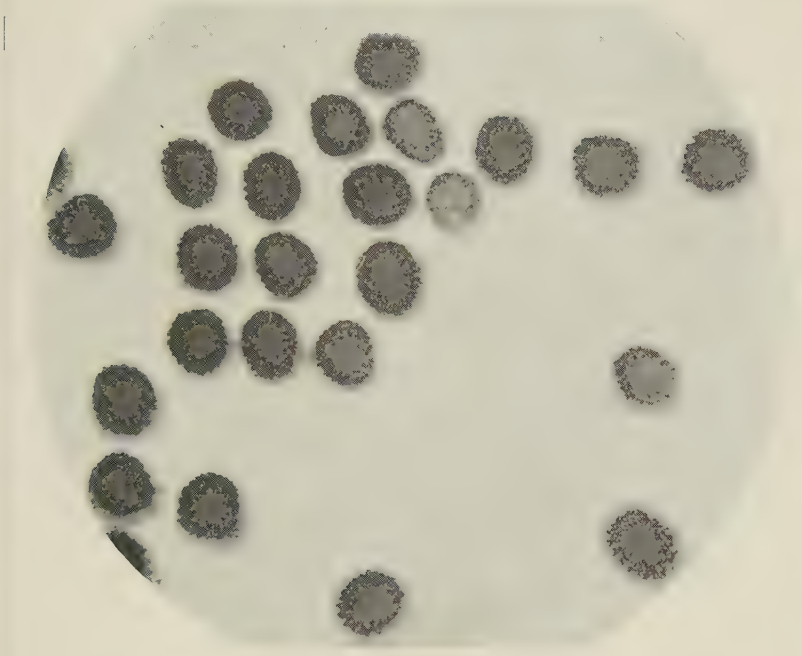
PLATE IV



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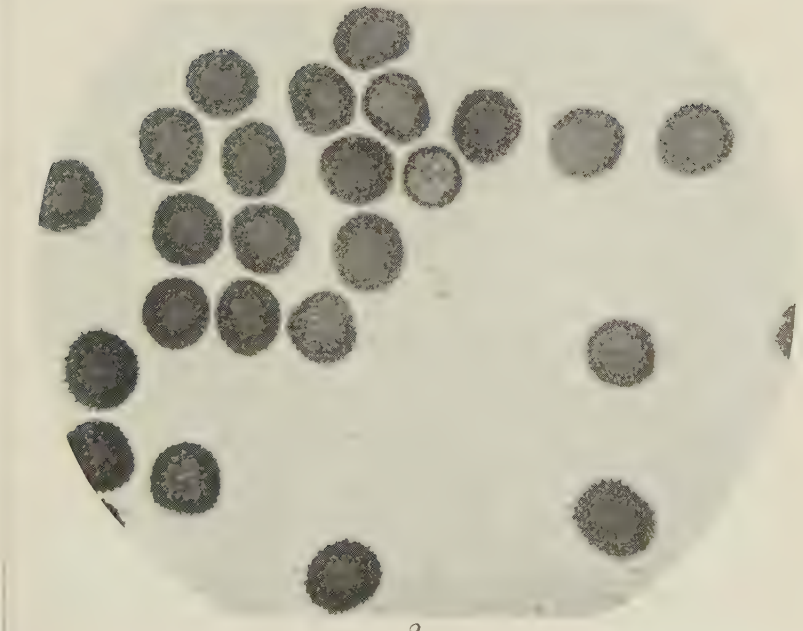

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PLATE V

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PLATE VI

PLATE VII

POSSIBILITIES OF DEVELOPING THE CASSAVA INDUSTRY IN THE PHILIPPINES

By F. T. Adriano

Chief, Agricultural Chemistry and Soil Technology
Bureau of Plant Industry, Manila

THREE PLATES AND ONE TEXT FIGURE

Cassava, scientifically known as *Manihot utilissima* Pohl., is called by different names. In the Philippines, it is commonly known as *balangay* or *kamonteng kahoy* in the Visayas, *bangala* in Lanao, *pangina* or *bingala* in Bukidnon, *kamote Moro* in the Ilocos, *pangi-kahoy* or *kamote-kahoy* in Sulu, *balinhoy* or *kamoteng kahoy* in the Tagalog provinces, *kamunte-kayo* in Zamboanga, *malamboanga* in Palawan, *padpadi* in Mountain Province.

In Malaya and in the Dutch East Indies, it is commonly known as *tapioca, cassava, mandioca,* and *manioc.* However the term *"tapioca"* usually refers to different forms of cassava products. In Cuba it is known as "yuca," a name of Brazilian origin.

While cassava has been grown in the Philippines for a long time, the plant having been introduced by early Spanish colonists, its cultivation has not been as extensively carried on as in other tropical countries.

According to the Division of Statistics of the Department of Agriculture and Commerce, the area under cultivation, production, and value of cassava raised in the Philippines in recent years, were as follows:

TABLE 1.—*Cassava statistics for the Philippines 1928–1932*

Year ending June 30	Cassava				
	Area cultivated	Production	Yield per hectare[a]	Average price[b]	Total value
	Hectares	*Kilos*	*Kilos*	*Peso*	*Pesos*
1928	16,154	23,427,500	1,450	0.02	521,200
1929	14,906	19,870,690	1,333	.02	428,630
1930	15,476	22,971,900	1,484	.02	502,570
1931	14,583	25,920,500	1,777	.03	673,330
1932	14,785	35,493,800	2,401	.02	766,590

[a] These figures are too low. [b] These figures are too high.

TABLE 2.—*Cassava; area under cultivation, production, and value for the year ending June 30, 1932*

Province	Area under cultivation	Production	Average		Value
			Yield per hectare	Price per 100 kilos	
	Hectares	*Kilos*	*Kilos*	*Pesos*	*Pesos*
Abra					
Agusan	40	92,300	2,307	2.35	2,170
Albay	435	1,388,300	3,191	2.48	34,420
Antique	151	337,700	2,236	2.82	9,520
Bataan	50	108,400	2,168	2.24	2,430
Batanes					
Batangas	225	446,200	1,983	3.48	15,530
Bohol	907	2,691,300	2,967	2.00	53,840
Bukidnon	211	709,600	3,363	1.82	12,930
Bulacan					
Cagayan	3	8,100	2,700	2.22	180
Camarines Norte	240	371,000	1,546	2.18	8,100
Camarines Sur	255	687,100	2,694	2.68	18,390
Capiz	1,124	3,738,400	3,326	2.16	80,650
Cavite	36	65,900	1,830	2.87	1,890
Cebu	1,182	2,652,400	2,244	2.47	65,410
Cotabato	238	670,400	2,817	2.72	18,210
Davao	158	407,900	2,582	2.70	11,000
Ilocos Norte	234	435,700	1,862	2.95	12,860
Ilocos Sur	55	114,800	2,087	3.55	4,080
Iloilo	188	338,000	1,798	2.76	9,320
Isabela	52	129,600	2,492	2.34	3,040
Laguna	67	134,700	2,010	3.22	4,340
Lanao	991	1,959,000	1,979	1.22	23,830
La Union	392	1,180,700	3,012	2.85	33,660
Leyte	255	611,600	2,398	1.80	11,040
Marinduque	78	170,500	2,186	1.65	2,810
Masbate	193	582,300	3,017	1.51	8,800
Mindoro	45	101,400	2,253	2.46	2,500
Mountain	15	43,000	2,867	1.44	620
Nueva Ecija	136	305,900	2,249	2.80	8,560
Nueva Vizcaya	33	70,800	2,145	2.37	1,680
Occidental Misamis	179	336,300	1,879	2.21	7,430
Oriental Misamis	26	59,100	2,273	1.56	920
Occidental Negros	197	555,300	2,819	2.32	12,870
Oriental Negros	1,150	2,526,400	2,197	1.99	50,400
Palawan	275	546,200	1,986	1.77	9,660
Pampanga	7	20,100	2,871	2.79	560
Pangasinan	395	989,600	2,505	2.13	21,090
Rizal	34	73,100	2,150	2.12	1,550
Romblon	232	764,000	3,293	1.62	12,410
Samar	1,048	2,031,100	1,938	1.97	40,120
Sorsogon	1,049	1,970,400	1,878	1.72	33,890
Sulu	748	1,962,800	2,624	2.44	47,940
Surigao	138	337,200	2,443	2.02	6,800
Tarlac	29	51,500	1,776	2.80	1,440
Tayabas	592	1,409,000	2,380	2.31	32,510
Zambales	139	250,100	1,799	1.98	4,950
Zamboanga	558	1,058,600	1,897	1.91	20,240
Philippine Islands	14,785	35,493,800	[a] 2,401	[b] 2.16	766,590

[a] This figure is too low. [b] This figure is too high.

In Malaya, the Dutch East Indies, Brazil, Cuba, and other countries cassava forms an important if not the main article of diet. Cuba in 1932, in order to encourage the development of the cassava industry, passed a law making it obligatory for baking establishments to mix with wheat flour cassava flour

to the extent of not less than 10 per cent nor more than 40 per cent in the preparation of bread and other bakery products. It might be of interest to quote hereunder that law.

LEY DECLARANDO OBLIGATORIO EL USO DE LA HARINA DE YUCA EN LA CONFECCIÓN DEL PAN

(Publicada en la Gaceta Oficial de 2 de enero de 1932)

SECRETARÍA DE AGRICULTURA, COMERCIO Y TRABAJO

GERARDO MACHADO Y MORALES, Presidente de la República. Hago saber: que el Congreso ha votado y yo he sancionado la siguiente,

LEY:

ARTÍCULO I.—A partir de la promulgación de esta Ley, quedan obligados los dueños de panaderías, a emplear en la confección de sus productos, tales como pan, galletas y sus similares un diez por ciento de harina de yuca, sin exceder de un cuarenta por ciento.

ARTÍCULO II.—Los infractores de la disposición contenida en el artículo anterior, serán multados desde treinta y un pesos a cien pesos por la primera infracción, y los reincidentes con pena de arresto de sesenta días a ciento ochenta, siendo competentes los Jueces Correccionales para imponer esos correctivos.

ARTÍCULO III.—Queda autorizado el Poder Ejecutivo para dictar el Reglamento para la mejor aplicación de esta Ley.

ARTÍCULO IV.—Esta Ley regirá a los diez y ocho meses de su publicación en la Gaceta Oficial de la República.

Por tanto, mando que se cumpla y ejecute la presente Ley en todas sus partes.

Dada en el Palacio de la Presidencia, en la Habana, a treinta y uno de diciembre de mil novecientos treinta.

(Fdo.) GERARDO MACHADO,
Presidente
(Fdo.) DR. E. MOLINET,
Secretario de Agricultura, Comercio y Trabajo

Comenzará la vigencia de esta Ley el día 2 de julio de 1932.

In Brazil, in spite of the fact that the cultivation of cassava is already well established, the Government, realizing its great commercial value and importance as an article of diet, and bent on giving this industry an additional measure of protection and encouragement, passed a resolution in 1922, authorizing the Ministry of Agriculture and Commerce to grant easy installment loans at 6 per cent interest under certain conditions, to farmers or corporations who would engage in the erection of factories.

If similar Government protection or encouragement is adapted here, the possibilities of developing the cassava industry would seem great.

To show the importance of and the need of developing the cassava industry here, and that every effort in this direction should be fully encouraged, it is only necessary to point out the heavy importations annually of wheat flour and starch. Wheat flour is also mentioned because of the possibility of displacing a certain proportion of it in the preparation of bread and other baking products by cassava flour.

TABLE 3.—*Quantity and value of starch and wheat flour imported into the Philippines from 1930 to 1933*

Year	Starch		Wheat flour	
	Quantity	Value	Quantity	Value
	Kilos	*Pesos*	*Kilos*	*Pesos*
1928	4,235,567	508,868	75,881,252	10,650,603
1929	3,261,105	441,063	77,595,086	10,120,155
1930	6,249,498	928,559	70,538,720	8,982,329
1931	5,948,222	702,917	79,013,252	6,429,237
1932	4,847,977	444,543	69,224,672	4,903,878
Average	4,908,474	605,190	74,450,596	8,217,240

The following table will show the commercial value and variety of products of cassava exported from Java for 1932.

TABLE 4.—*Principal exports of cassava or tapioca products from Java in 1932*

[Weights in 100 tons.]

Destination	Gaplek	Gaplek meal	Tapioca flour	Tapioca flake	Tapioca pearl
U. S. A.		24	526	13	21
Denmark		196			
Norway		169			1
Japan	184	12			
Belgium and Luxemburg		60	28		10
Netherlands		15	19	4	6
United Kingdom	4	121	89	33	36
Germany		2			1
France			4		
Spain	217			1	
Sweden	4				
Australia					3
Italy		221	2		
China			20		2
British India			20		22
Penang					
Singapore			14		
Indo-China			1		
Hongkong			46		1
Philippines			21		1
Canada			1		5

There are numerous varieties of cassava in cultivation at the present time most of which are of foreign introduction and many more are being discovered as a result of crossing. However, in Java, it is claimed that more than two dozen varieties are considered of commercial value. In the Philippines also many varieties are known. Cassava can be classified into the so-

called "sweet" or edible and "bitter" or poisonous varieties. Sweet or edible varieties are reported to contain from 0.014 to 0.042 per cent in the bark and from 0.003 to 0.015 per cent hydrocyanic acid in the edible portion and the "bitter" or poisonous varieties from 0.012 to 0.056 per cent in the bark and from 0.013 to 0.037 per cent of hydrocyanic acid in the flesh. The author has devised a rapid method of testing hydrocyanic acid in cassava tubers which is suitable for field tests. Reference to this article is given at the end of this paper.

For the manufacture of starch the bitter and high yielding varieties which are rich in starch are preferred. These latter varieties are less subject to the depredations of both men and animals. Table 5 gives the differences in composition of some important varieties grown in the Philippines. For other agronomical and botanical data, the reader is referred to either the Director of Plant Industry or the College of Agriculture.

CULTURE AND CHEMICAL COMPOSITION OF CASSAVA

Cassava can be grown in almost any kind of soil provided with good drainage, but soil that is light, sandy and well irrigated as well is considered the best.

The plant is propagated by stem cuttings usually 15 to 22 cm in length which are planted vertically after the soil has been properly prepared. The distance recommended for planting varies, but planting one meter apart each way, which will give 10,000 points to the hectare, is the method commonly practiced.

The cultivation should begin when the plants are about 30 cm high. Usually two to three weedings are sufficient, after which the plants will have covered practically the whole space, thus preventing the growth of weeds.

Depending on the variety, soil, and climatic conditions, the tubers are ready for harvest when they are about eight to fourteen months old. In other places the harvesting is not done even until as late as eighteen months after planting.

The yield per hectare of fresh tubers varies greatly, according to several factors, such as variety, soil fertility, climate, cultivation, age of plant, etc. In the Philippines it is reported that the average production is about 10 tons per hectare, although with proper seed selection, the right variety, and the use of good cultural methods, this yield can be raised considerably. In Java, yields as high as about 44 tons per hectare have been reported.

In Bataan and Zambales, the yield runs to 20 or more tons per hectare it is said. Assuming a yield of only 2 kilos per

tuber or hill or plant and 10,000 hills to the hectare when a 1–by–1 meter planting distance is followed, a yield of 20 tons per hectare can be obtained. Experiments, however, have shown that by proper methods of culture, it is possible to secure 3 to 4 kilos of tubers per hill thus giving a yield of 30 to 40 tons per hectare.

The author and his coworkers have analyzed many varieties of cassava; the average composition is given as follows:

	Per cent
Edible portion	81.40
Moisture	63.80
Ash	1.44
Proteins	0.96
Fats	0.26
Hydrocyanic acid	0.02
Crude fiber	0.85
Starch	27.65
Nitrogen free extract (carbohydrates)	5.04
Calorific value per kilo (calories)	1,403.00

Table 5 gives the yield per hectare and analysis of some important varieties.

TABLE 5.—*Yield of cassava per hectare and the chemical composition of some important varieties grown in the Philippines* [a]

Variety	Yield of tubers in tons per hectare			
	P. I.		Java	
	Tubers	Starch	Tubers	Starch
Mandioca Sao Pedro Preto [b]	38.5		44.79	11.92
Mandioca Basiacao	37.92	9.80		
White Native			16.40	5.24
Red Native	23.78	7.63		
Rough Internode	26.29	6.90		
Baker	33.15	10.09		
Colored or Red	27.43	9.16		
Singkong Manis	27.18	6.17		
Kapo Colorado	32.85	10.60		

Variety	Chemical analysis (Results expressed in per cent)						
	Moisture	Protein	Fats	Ash	Carbohydrates		
					Crude fiber	Starch	Total
Mandioca Sao Pedro Preto [b]	59.68	0.57	0.35	1.25	0.87	31.89	32.76
Mandioca Basiacao	68.31	0.50	0.05	1.06	0.67	26.26	26.93
White Native	57.42	0.40	Trace	1.00	1.23	31.77	33.00
Red Native	59.81	0.42	Trace	0.95	0.90	30.96	31.86
Rough Internode	59.62	0.61	0.11	1.19	0.75	29.06	29.81
Baker	60.16	0.43	Trace	1.09	0.90	30.42	31.32
Colored or Red	56.45	0.60	Trace	1.22	0.69	33.39	34.08
Singkong Manis	60.39	1.38	0.13	1.48	1.11	26.38	27.49
Kapo Colorado	58.70	0.60	Trace	0.86	1.04	32.26	33.30

[b] Yield computed from experiments in Lamao and Los Baños. [b] Poisonous.

PRODUCTS OF CASSAVA

Cassava can be converted into a variety of products, the most important of which are given as follows:

Cassava flour.—In Malaya, the Dutch East Indies, Brazil, Cuba and other tropical countries, cassava flour is used in the preparation of many articles of diet.

Tables 6 and 7 will show the value of cassava flour for bread making as compared to wheat and other cereals:

TABLE 6.—*Chemical analysis of cassava and important cereal flours*

	Cassava	Corn	Wheat	Rice
	Per cent	*Per cent*	*Per cent*	*Per cent*
Moisture	10.75	13.41	13.65	13.12
Protein	0.87	7.56	12.35	9.85
Fats	1.19	2.79	1.75	0.88
Ash	1.24	1.78	1.81	1.51
Crude fiber	6.12	3.19	2.53	0.63
Carbohydrates	79.83	71.27	67.91	74.01

TABLE 7.—*Analysis of bread made from different flours*

	Wheat	Wheat with 25 per cent Cassava	Cassava
	Per cent	*Per cent*	*Per cent*
Moisture	25.19	20.84	24.15
Proteins	10.14	8.76	6.54
Fats	1.28	1.15	1.73
Ash	1.25	0.72	1.39
Crude fiber	1.60	1.19	0.72
Carbohydrates	60.54	67.34	65.83

Starch.—Cassava is an important raw material in the preparation of cassava starch, which is known in the Philippines as "gaogao." Cassava starch is used for laundrying purposes. It is also used in sizing yarns and cloths, in the preparation of the so-called British gums, dextrins, and pastes, and in the manufacture of confectioner's glucose, of which increasing quantities are annually used here. Of the last item alone more than 100,000 pesos' worth is annually imported.

In the manufacture of food, it is used in the preparation of custards, blanc mange, puddings, powder, macaroni, simolinas, and sauces, as a thickening agent in ice cream, and as fillers for various kinds of food products. It is also mixed with breakfast cereals.

Gaplek.—A malay term which refers to the dried and peeled or unpeeled roots of cassava. Gaplek is produced in large quantities in certain parts of Java and exported (see Table 4) to

Europe, Japan, and other countries as a raw material for the preparation of industrial alcohol and low-grade starch.

Pearl and flake tapioca.—These are used mainly for human consumption. Pearl tapioca is in the form of small spheres and consists of starch grains cemented together by the dextrin formed in the course of its manufacture. Flake tapioca consists of small spheres cemented together in an irregular manner. Both products are very pure carbohydrate foods, making delicate puddings, thickening for soups, and food for infants and the sick.

Feed for livestock.—Cassava forms a very satisfactory forage material and in combination with molasses and other foodstuffs to supply the nitrogenous and other necessary dietary elements, makes an excellent feed for livestock.

Dextrin.—As a source of dextrin, which is now used commercially as a substitute for the more expensive gum arabic and as a paste for book binding and similar uses, cassava starch is being used rather extensively.

Glucose.—Either in the form of a thick syrup or as a powder which is very much used in the confectionery industries.

Other uses.—It has also been used in the manufacture of beer, alcohol, vinegar, etc.

In view of the commercial importance of cassava starch and the possibilities of developing the cassava industry with starch as the main product, although other useful cassava products can be prepared later, I shall endeavor in the following pages to describe the processes used in its manufacture in an effort to arouse interest in the development of such a very important and yet neglected cassava industry in the Philippines.

THE MANUFACTURE OF STARCH FROM CASSAVA

In view of the great economic importance and value of starch, a description of the manufacture of this article from cassava should prove interesting and hence will be given hereunder.

Using the average quantity of starch imported into the Philippines as 5,000 tons and assuming that the average yield per hectare as has been reported here is 10 tons (although this yield should be considerably higher when proper cultural and manurial methods are followed) and assuming further that the average efficiency of the factory is 18 per cent recovery (although in Java 20 to 30 per cent are reported) it would require 28,000 tons tubers of cassava to produce this amount of starch and 2,800 hectares of land to produce this quantity of tubers. The

present production of tubers is mostly used for food or animal feed and very little is available for starch manufacture. There is therefore need of increasing the hectarage, improving the yield by use of right varieties and cultural methods, and employing more efficient methods of manufacturing the finished products.

A factory of 10 tons per day of twenty hours if it works on the basis of two hundred days in a year will require 2,000 tons tubers; and to produce the quantity of starch needed by the Philippines (5,000 tons), fourteen factories of the above capacity would have to be erected. The establishment of only six factories of this capacity as a start would mean employment to a large number of laborers, many of whom are at present idle. Besides it would develop a very important industry which has commercial possibilities.

In the Philippines, however, there are at present only a few starch factories, some of which are as follows:

1. Bataan Starch Factory, Samal, Bataan
2. Caosep Starch Factory, Naga, Camarines Sur
3. Philippine Starch and Sugar Factory, Janiway, Iloilo
4. Naic Starch Factory, Naic, Cavite

As far as we are aware only two or three factories are provided with the right kind of machinery and are actively functioning. The others, for some reason or other are not working. It is, however, reported that one of the causes for the failure of some factories to operate is the lack of sufficient raw materials, the factory having been erected before the plantation was established.

While cassava is grown throughout the Philippine Islands, there are only few plantations which are sufficiently large to supply the raw materials needed for a starch factory. There is need of starting plantations or getting planters under contract say for ten or five years to supply the raw materials, a contract similar to that used by the sugar centrals would seem satisfactory. While there are many small planters who are anxious to manufacture starch by the use of small machines, it is doubtful whether a factory of less than 5 tons per day can operate economically and produce starch which could compete with that coming from foreign countries.

There are a number of firms in Manila which can import starch-making machinery. Some of these are the Philippine Engineering Company, the Pacific Commercial Company, Fred Wilson Company, Smith, Bell and Company, Aguado Hermanos,

and others. These companies will be glad to furnish quotations to parties who are seriously contemplating the erection of starch factories.

Mr. Joaquin Joson, owner of the Bataan Starch Factory, has kindly placed at my disposal all data regarding his factory and using these and other data I have attempted to prepare a prospectus for starch factories of 5 tons and 10 tons of fresh tubers per day of ten and twenty hours' run. In the preparation of the prospectus which will be given hereunder, the year is considered as of only two hundred working days, although at other times of the year when the factory is not busy grinding cassava root, arrowroot or other tubers could be used as the raw materials in order to make the mill operate for as much of the year as possible and hence pay better.

In the following pages, I shall also attempt to describe the manufacture of starch from cassava using modern machinery.

Fresh tubers, which should not be more than 24 hours old, are delivered to the factory and immediately put into the washing machine, which is a large rotating perforated cylinder provided with squirt tubes so as to effect a thorough washing and cleaning of the tubers.

From the washing machine the clean tubers go directly to a grater that is operated at 2,000 revolutions per minute, thus reducing the tubers to a smooth pulp which is then pumped into a tank that is provided with an outlet tube. The grated pulp is treated with water and then led to twin circular oscillating sieves for washing out the starch. The strained liquid, consisting of starch in suspension goes to the repassing and refining sieves. From the oscillating sieves the residue or bagasse is recovered and this bagasse is sold to hog raisers at the rate of 10 centavos per kerosene canful.

From the refining sieves, the starch in suspension is led to what are known as starch tables. In the Mr. Joson's factory these tables are made of concrete. There are sixteen starch settling tables each measuring 25 cm wide by 24 meters long. In the starch tables, the water is run off at other end of the tables and the starch is allowed to settle therein. The settled starch is then sent to a sulphuring tank where it is treated with sulphurous acid prepared by burning sulphur in a sulphuretor. For 5 tons tubers a day, about 2 to 3 kilos of sulphur powder are burned.

From the sulphuring tank, the bleached starch is sent to another tank for washing out the excess acid. The washed

starch is mixed with a little water and then pumped up to a wooden tank, which is provided with a stirring device, thus keeping the starch in suspension, which is usually the consistency of thin condensed milk; and is dropped to a centrifuge that is used to separate the starch from the water adhering. From the centrifuge the starch that has been freed from as much water as possible, is conveyed to the drier. The dryer consists of a chamber provided with 260 sheets of plain 20-gauge galvanized iron on which the centrifuged starch is placed for drying. The dryer is provided with a big fan that drives the hot air in proper circulation, thus effecting efficient and rapid drying of the starch. From the dryer, the dried starch, which is obtained in lumps is sent to a grinder for grinding into a fine powder.

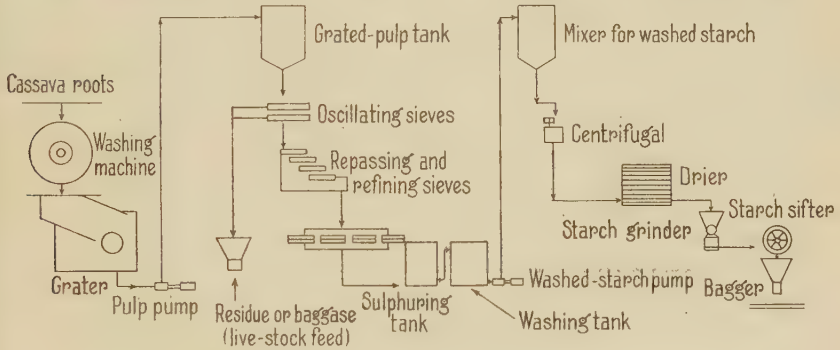

FIG. 1. Flow sheet for cassava-starch manufacture

The ground starch is dropped to a big shifter provided with silk bolting sieves of about 200-mesh. The shifted starch is then placed in jute bags. Usually the starch is bagged in a sack of 1 picul, or 63 kilos, although it is claimed that more profit is realized when the starch is bagged in kilo packages. However, the latter entails more attention and expenses.

The flow sheet for a cassava starch factory, here described, is shown in fig. 1.

COST OF MANUFACTURING CASSAVA STARCH

Using Mr. Joson's data and the current prices of the starch and the present scale of wages, I present a prospectus for a starch factory to take care of 5 tons and 10 tons of fresh tubers a day of ten and twenty hours, respectively. It will be seen that when properly managed the manufacture of starch from cassava is a paying proposition. Space does not permit the detailed discussion of all the operations and points that should

be considered. In the prospectus, it is only assumed that the factory buys fresh tubers from the planters around the factory, although it is reported that more profits can be realized if the factory conducts its own plantation. Interested parties who may wish to secure additional data will be furnished the information on application.

1. Prospectus for a cassava starch factory with a capacity of 5 tons of tubers a day (10 hours) when tubers are bought

		Pesos
A. EQUIPMENT		
(*a*) Complete starch machinery with 20-horse-power engine		24,250.00
(*b*) Galvanized iron, plain, 20-gauge, 260 sheets at 4 pesos		1,040.00
(*c*) Shed, starch tables, pipings, installation, etc		8,000.00
(*d*) One 2-ton delivery truck		1,750.00
		35,040.00
B. OPERATING EXPENSES		
(*a*) Tubers delivered to factory, 5 tons at 5 pesos	25.00	
(*b*) Fuel, 5 cart loads at 1 peso	5.00	
(*c*) Lubrication	1.00	
(*d*) Jute bags, 15 at 15 centavos	2.25	
(*e*) Light	1.00	
(*f*) Labor, 1 mechanic and 5 laborers	5.00	
(*g*) Overhead and incidental	3.00	
Total	42.25	
(*h*) Assuming 200 working days, at 42.25 pesos		8,450.00
(*i*) Transportation		1,000.00
(*j*) Registry, taxes, and propaganda		500.00
(*k*) Repairs and incidental		200.00
(*l*) Depreciation on equipment at 10 per cent		3,504.00
(*m*) Interest on operating expenses at 10 per cent		1,015.00
		14,669.00
C. INCOME		
(*a*) Starch, 14 piculs at 7 pesos	98.00	
(*b*) Bagasse, 150 5-gallon cans at 10 centavos	15.00	
	113.00	
(*c*) Assuming 200 working days, at 113 pesos		22,600.00
(*d*) Total expenses under I–B		14,669.00
Income		7,931.00

II. Prospectus of a cassava starch factory with a capacity of 10 tons of tubers in 20 hours when tubers are bought

		Pesos
A. Equipment. Same as I–A		35,040.00
B. Operating Expenses		
(*a*) Tubers, 10 tons at 5 pesos		50.00
(*b*) Fuel, 10 cart loads at 1 peso		10.00
(*c*) Lubrication		2.00
(*d*) Jute bags, 30 at 15 centavos		4.50
(*e*) Light		2.00
(*f*) Labor, 2 mechanics and 10 laborers		10.00
(*g*) Overhead and incidental		5.00
(*h*) Assuming 200 working days		16,700.00
(*i*) Transportation		2,000.00
(*j*) Registry, taxes, and propaganda		1,000.00
(*k*) Repairs and incidental		500.00
		20,200.00
(*l*) Depreciation on capital at 10 per cent		3,504.00
(*m*) Interest on expenses at 10 per cent		2,020.00
(*n*) Operating expenses		20,200.00
		25,724.00
C. Income		
(*a*) Starch, 28 piculs at 7 pesos	196.00	
(*b*) Bagasse, 300 5-gallon cans at 10 centavos	30.00	
	226.00	
(*c*) Assuming 200 working days, at 226 pesos		45,200.00
(*d*) Total expenses under II–B		25,724.00
Gross income		19,476.00

REFERENCES

1. Adriano, F. T. The proximate chemical analysis of Philippine foods and feeding stuffs. Philip. Agr. 14 (1925) 57–91.
2. Adriano, F. T., and Santos, F. O. The chemical composition of Philippine food materials. Public Welfare Commission Circular. Bur. of Print., Manila (1928).
3. Adriano, F. T., et al. The proximate chemical analysis of Philippine foods and feeding stuffs. III. 20 (1932) 530–534.
4. Adriano, F. T., and Ynalvez, L. A rapid method of detecting and estimating hydrocyanic acid suitable for field tests. Philip. Journ. Agr. 3, (1932) 105–109.
5. Adriano, F. T., et al. The preparation of rice and other flours and their commercial utilization. (In press.)
6. Anonymous. Annual reports of the Insular Collector of Customs of the P. I. Bur. of Print., Manila (1930–1933).

7. GALANG, F. G. Experiments on cassava at the Lamao Experiment Station, Bataan. Philip. Journ. Agr. 2 (1931) 179–188.
8. GREENSTREET, V. R., and LAMBOURNE, J. Tapioca in Malaya S. S., and Federated Malay States. Gen. Series No. 13, Kuala Lumpur (1933).
9. LEACH, A. E. Food inspection and analysis. (Translated by A. L. Winton.) John Wiley and Sons, Inc., New York (1913).
10. MENDIOLA, N. B. Cassava growing and starch manufacture, Coll. of Agr. Exp. Sta. Cir. No. 21, Los Baños, Laguna.
11. 1932—Cultivo, Industrias, y Comercio de Yuca. Revista de Agricultura, Comercio y Trabajo. Edición extraordinaria. Habana, Cuba (enero, 1932).
12. WESTER, P. J. Food plants of the P. I. Bur. of Agr. Bull. 39 (1925).

ILLUSTRATIONS

Plate I

Fig. 1. Bataan Starch Factory, Samal, Bataan, Province, Luzon, showing the washing machine, grater, and drier.

2. Bataan Starch Factory, showing the oscillating sieves, repassing and refining strainer, and the starch tables.

Plate II

Fig. 1. Bataan Starch Factory, showing the sulphuring, washing, and mixing tanks and the centrifuge.

2. Bataan Starch Factory, showing the sifter and drier.

Plate III

Fig. 1. Young cassava plants, Singalong, Manila.

2. Cassava roots or tubers, the raw material for the manufacture of starch and other cassava products.

Text figure

Fig. 1. Flow-sheet for cassava starch manufacture.

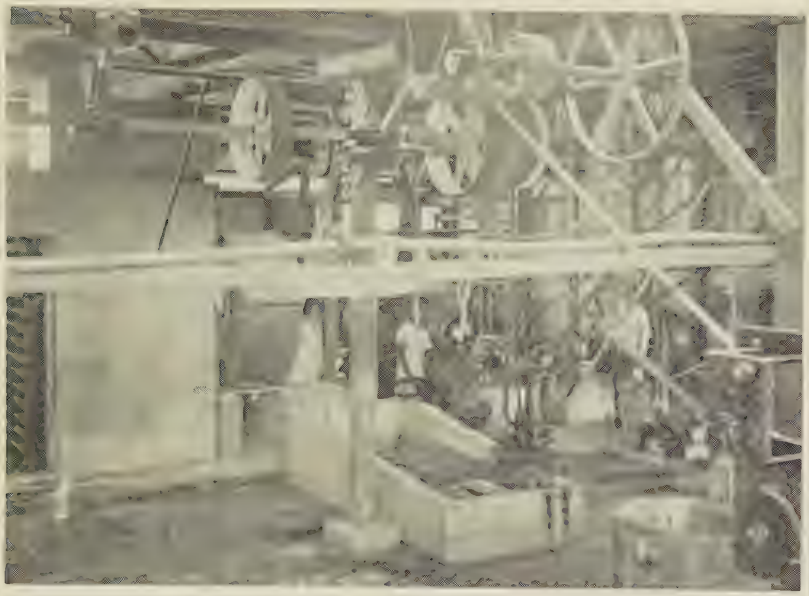

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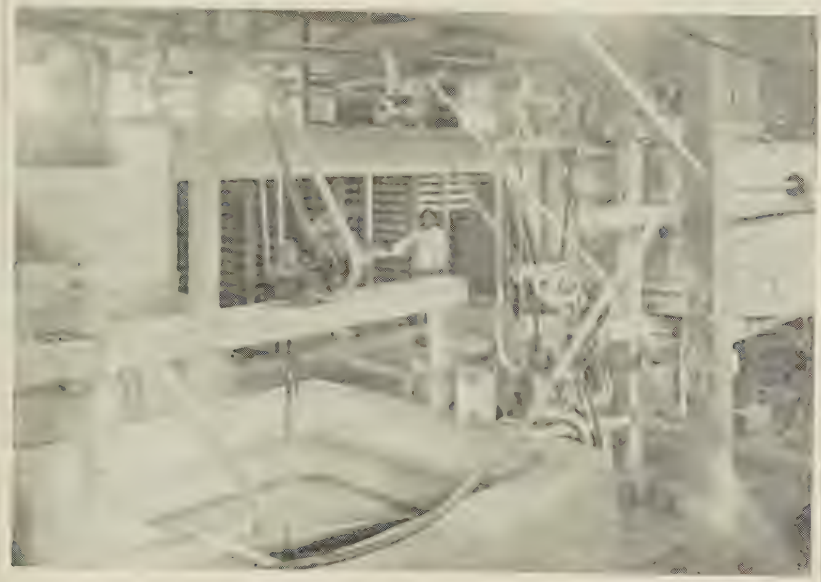
PLATE I



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